Quench Positions in TQC Models
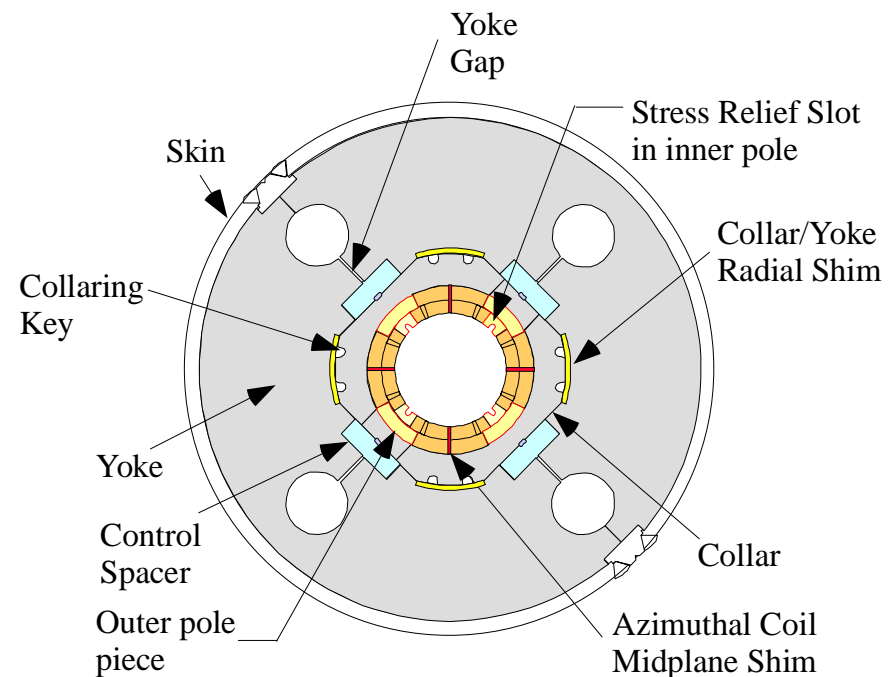
Rodger Bossert

Technical Division Technical Memo #TD-08-031
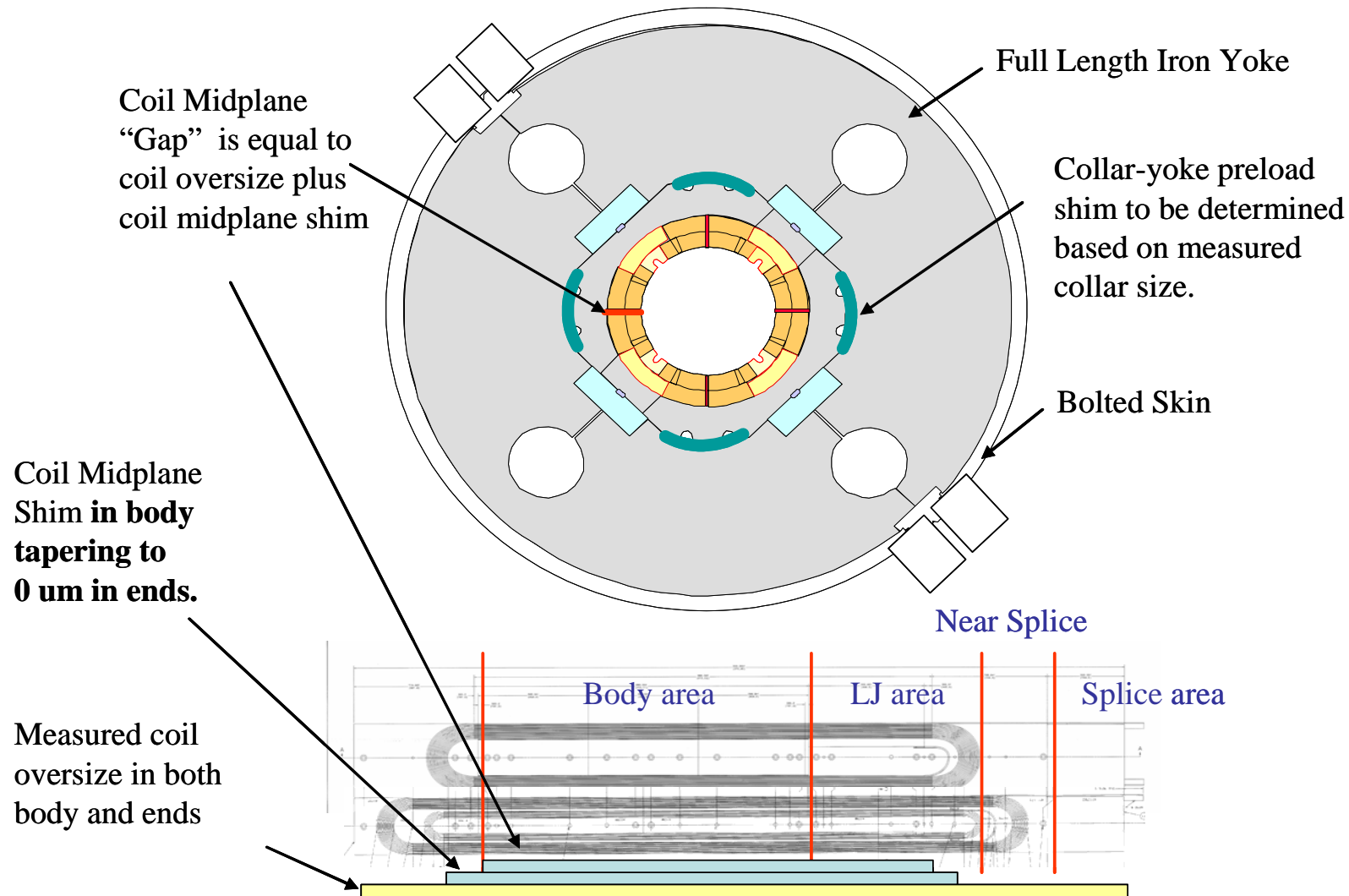September 29, 2008

Technology Quadrupole - TQC

Features:

- **Traditional collared coil with stainless steel shell.**

- **Preload shared by collars and shell.**

- **Preload applied primarily at room temperature.**

Yoke Gap

Stress Relief Slot in inner pole

Skin

Collar/Yoke Radial Shim

Collaring Key

Yoke

Control Spacer

Collar

Outer pole piece

Azimuthal Coil Midplane Shim

Preload Application - TQC

Coil Midplane "Gap" is equal to coil oversize plus coil midplane shim

Full Length Iron Yoke

Collar-yoke preload shim to be determined based on measured collar size.

Coil Midplane Shim **in body tapering to 0 um in ends.**

Bolted Skin

Measured coil oversize in both body and ends

Near Splice

Body area   LJ area   Splice area

Magnet Tests - TQC

Magnet	Conductor	Coils	Island	Temperature	Test
TQC01a	MJR (1900 A/mm2)	**9, 10, 12, 13**	Bronze	4.4 K & 1.9K	Aug 2006 FNAL
TQC01b	MJR	7, 8, 10, 12	Bronze	4.4 K & 1.9K	May 2007 FNAL
TQC02E	RRP (2800 A/mm2)	20, 21, 22, 23	Titanium	4.4 K & 1.9 K	Nov 2007 FNAL
TQC02a	RRP	17, 19, **24, 27**	Bronze	4.4 K & 1.9 K	Jan 2008 FNAL
TQC02b	MJR/RRP	10, 12, 17, 19	Bronze	4.4 K & 1.9 K	Aug 2008 FNAL

Virgin coils in bold.

Coils with non-glued poles and pole slots in red.
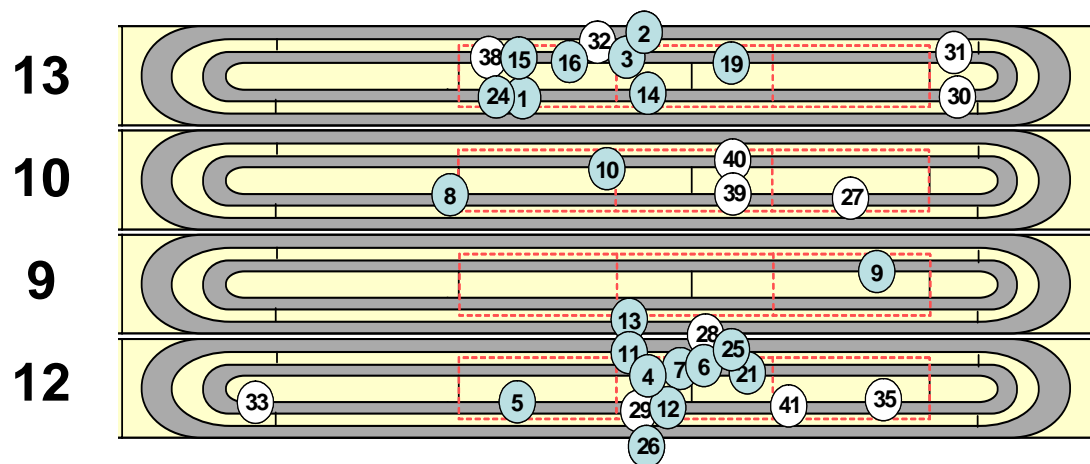
TQC01 Quench History
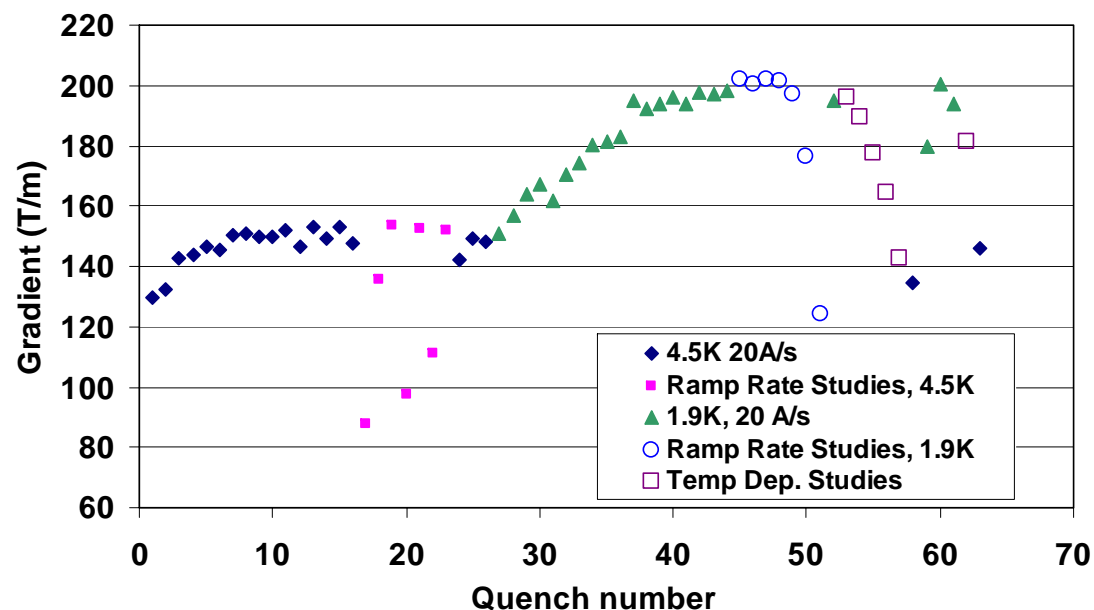
- **Low plateau (72% of SSL) at 4.5K with all quenches in inner layer pole turn.**

- **Better performance (87% SSL) at 1.9K.**

- **Eventual degradation in outer layer lead area in 2 coils.**

- **Almost all quenches in area where outer poles are not glued.**

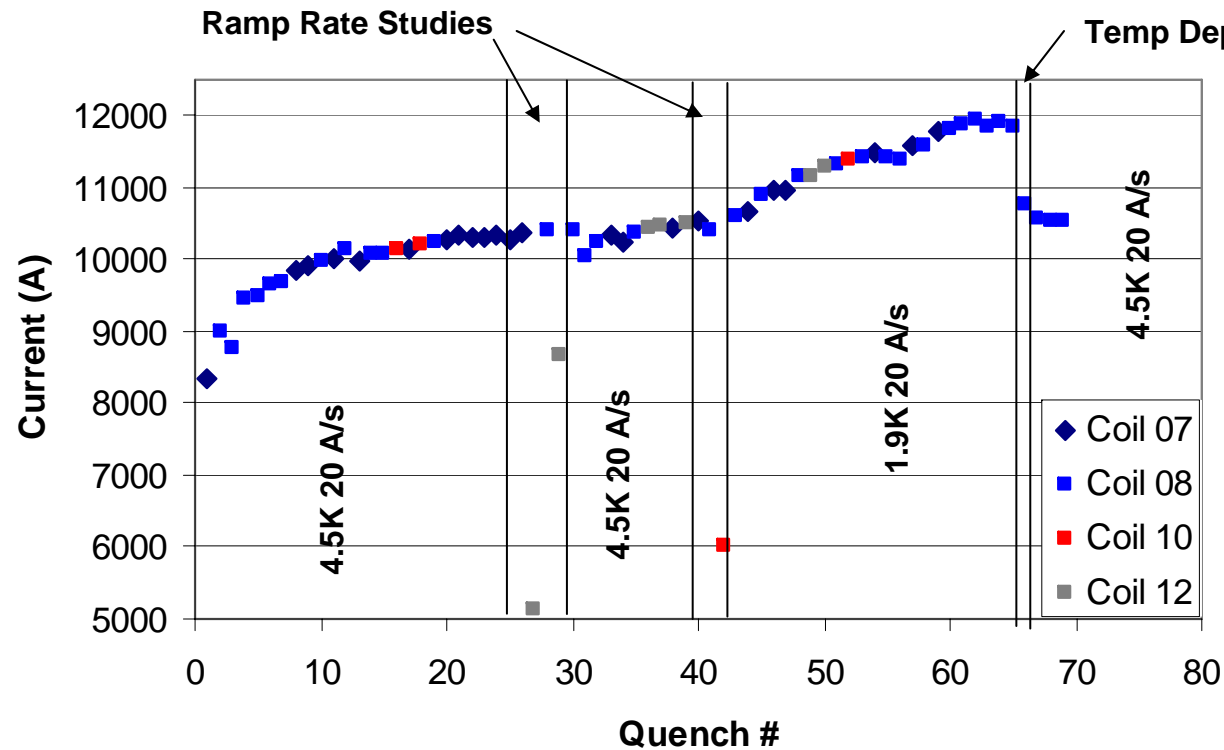- **Very few quenches in end areas.**
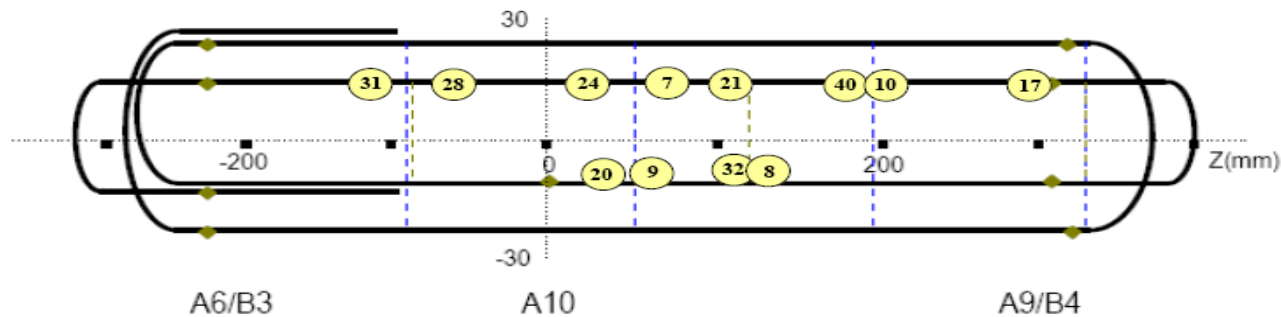
TQC01b Quench History

• **Higher preload gave quench performance similar to that from the coils in TQS01 series.**

• **Same coils have same performance in the different structures.**

• **1.9K behavior similar to other MJR coils (as expected).**

• **Magnet was disassembled, and coils reused** without **degradation.**
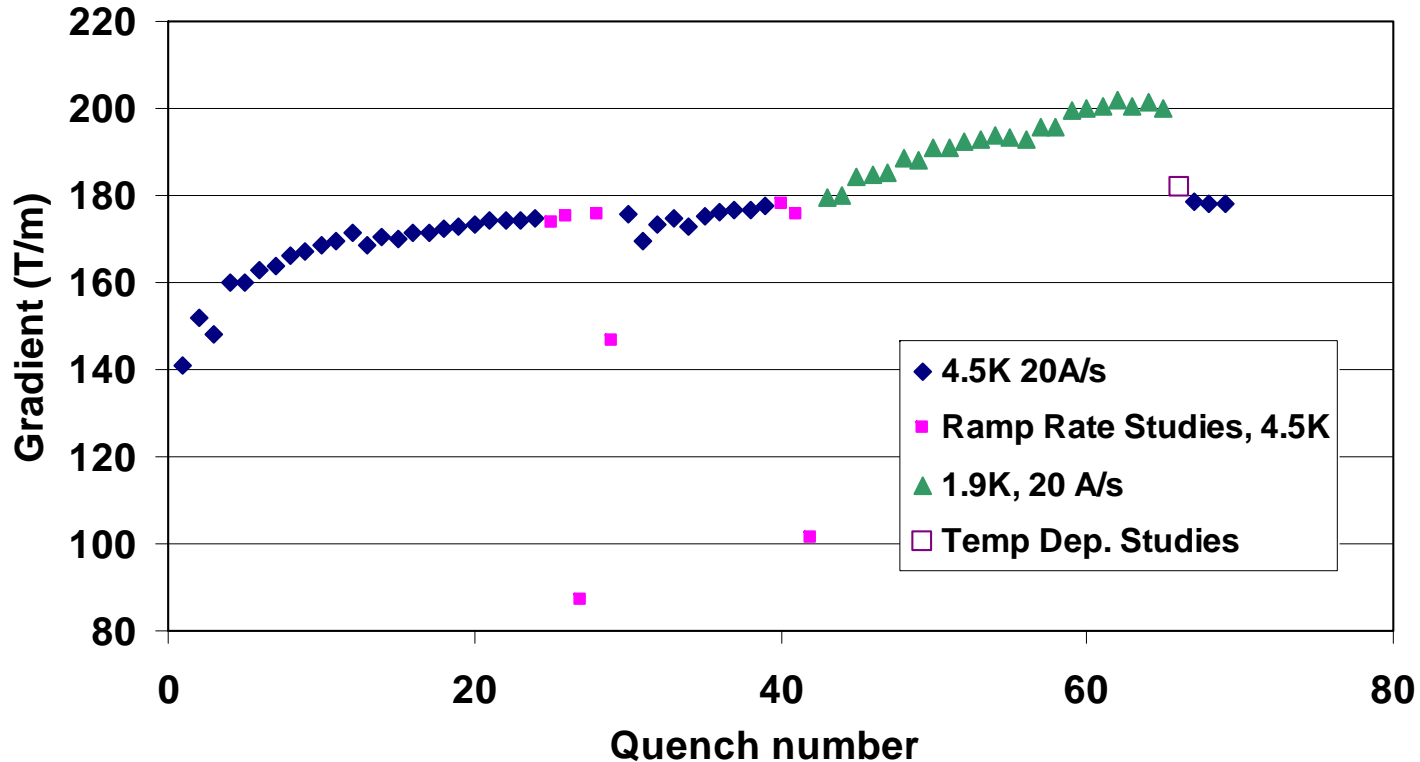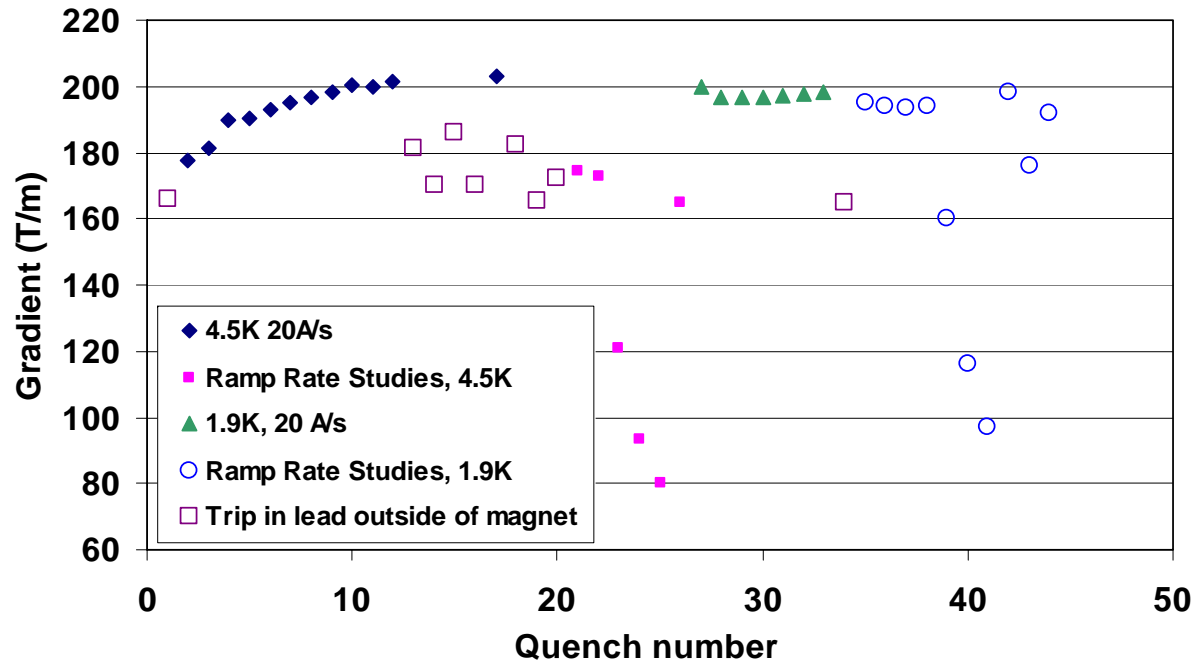
TQC01b Quench History by Coil

Training quenches in all four coils, but more in coils 7 and 8

Quench positions of training quenches
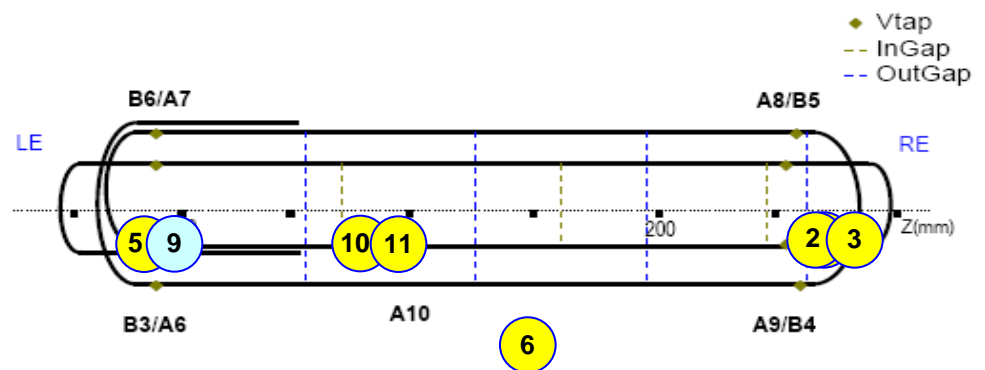
TQC02E Quench History

4.5 K:
Quenches: #2,3,5,6,10,11 - in coil 20 Quench # 6 in outer layer mid-plane
Quench # 9 – coil 21

1.9 K:
All quenches in outer layer mid-plane segment of coil 21

Quenches at high ramp rates: All in coils 22 and 23, mid-plane segments, both inner and outer coil layer

- **Similar training behavior as TQS02a with same coils.**
- **1.9K behavior similar to other RRP coils, seemingly limited by instabilities.**
- **Training at 4.5K not complete due to quenches in leads.**
- **Magnet was disassembled, and coils reused several times without degradation.**

TQC02a Quench History

TQC02a Quench History Key to zones: (1) 4.5K 20A/s, (2) 4.5K ramp rate studies, (3) 1.9K 20 A/s, (4) 1.9K ramp rate studies, (5) Temp Dependence studies, (6) 4.5K ramp rate studies, (7) 4.5K 20 A/s
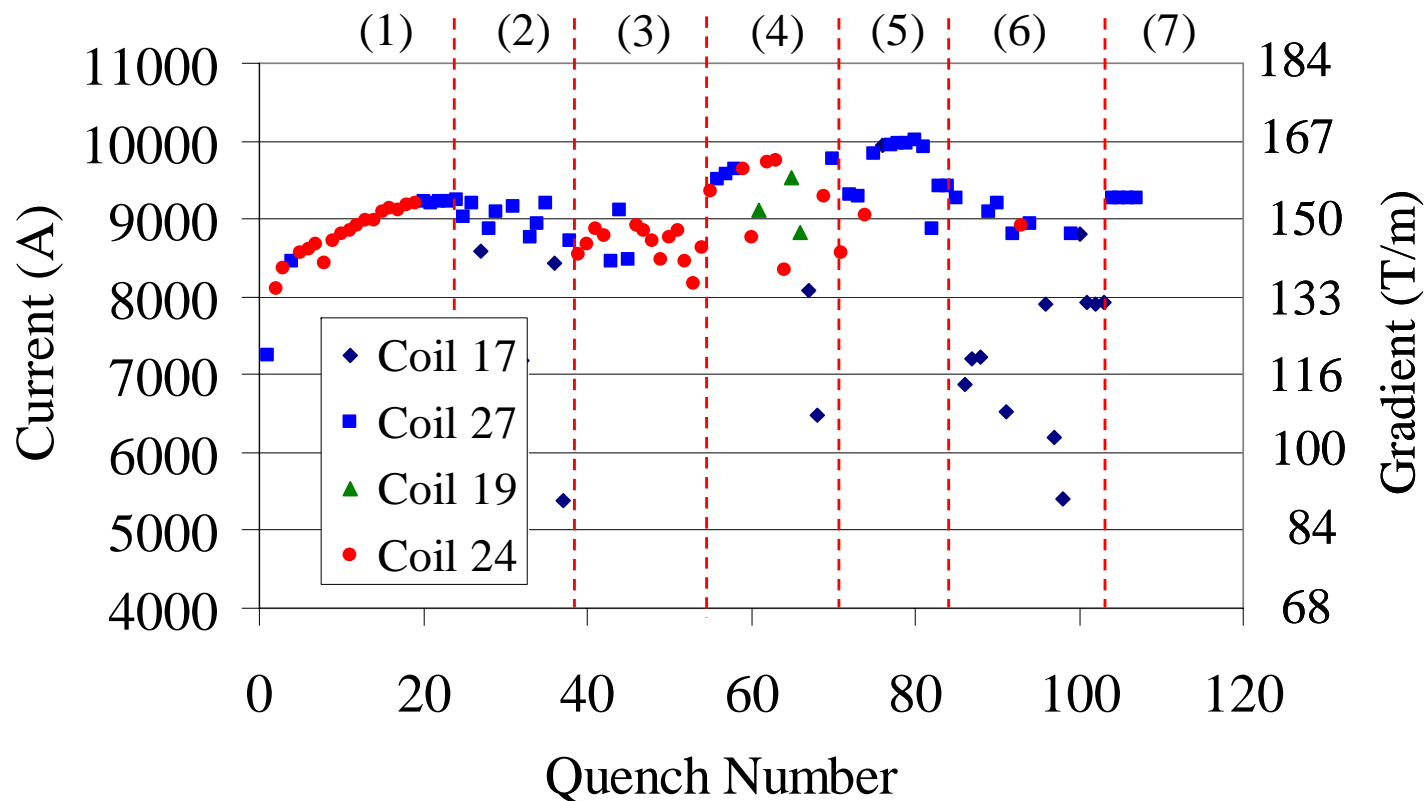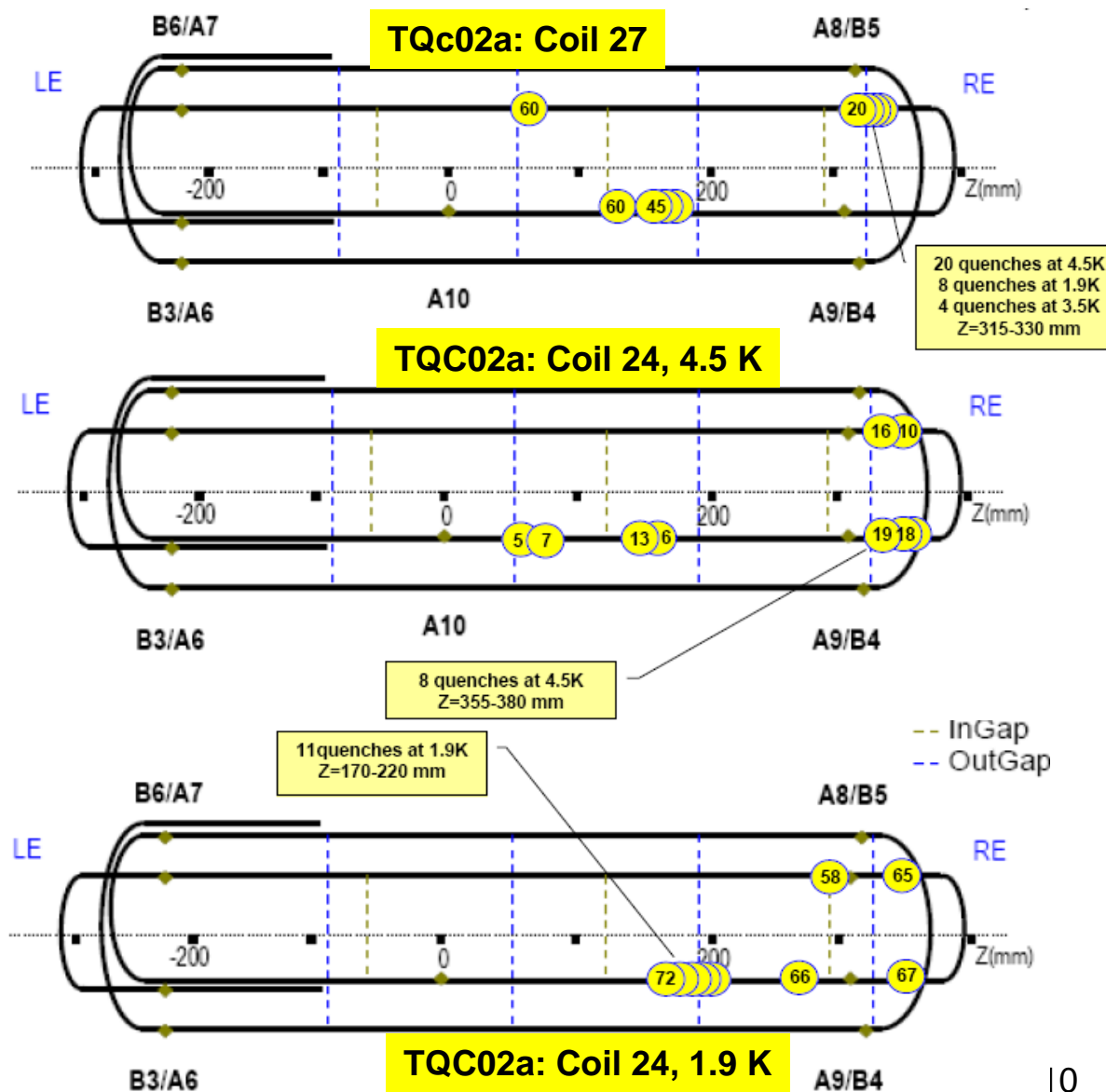

Slow linear training in coil 24 until quench position changed to coil 27, at a specific position near the return end and current of 9250A, 68% of the SSL.

1.9K training was similar to other RRP models, erratic and not better than at 4.5K. However, most quenches even at 1.9K were in the inner coil pole turn.

TQC02a Quench Positions

- **Training quenches all in coils 24 and 27, in the inner coil pole turn but near the junction between outer pole pieces.**

- **Many, including the limiting quenches in Coil 27, near the return end.**

TQc02a: Coil 27

20 quenches at 4.5K
8 quenches at 1.9K
4 quenches at 3.5K
Z=315-330 mm

TQC02a: Coil 24, 4.5 K

8 quenches at 4.5K
Z=355-380 mm

11 quenches at 1.9K
Z=170-220 mm

**TQC02a: Coil 24, 1.9 K**

-- InGap
-- OutGap

TQC02b Quench History

TQC02b training at 4.5K proceeded in a slow but linear path, with all training quenches at 4.5K in the same coil (12). At 1.9K, all training quenches also in coil 12, except two in coil 17.
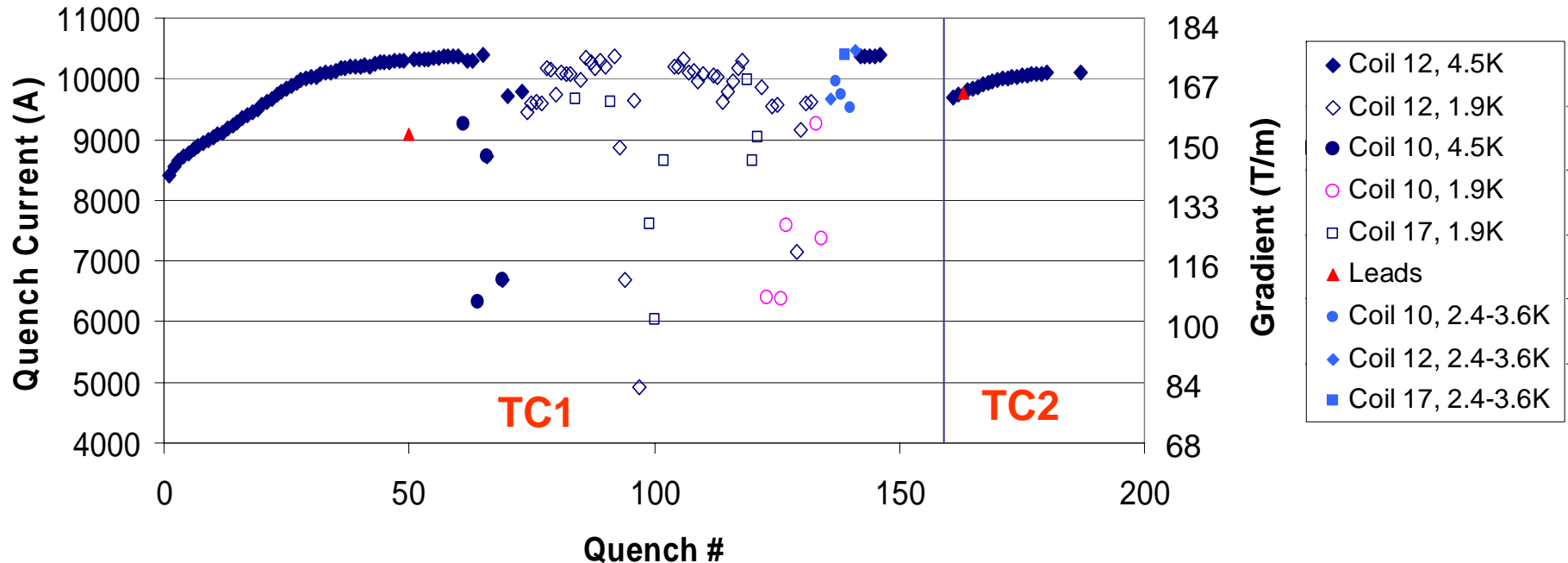
- **Plateau at 4.5K was reached at 10382A, about 84% of the critical current limit, almost identical to that of TQC01b.**
- **Behavior at 1.9K is erratic, still unexplained.**
- **Return to same plateau when returned to 4.5K.**
- **Some retraining during 2nd thermal cycle.**

TQC02b Quench Positions at 4.5K
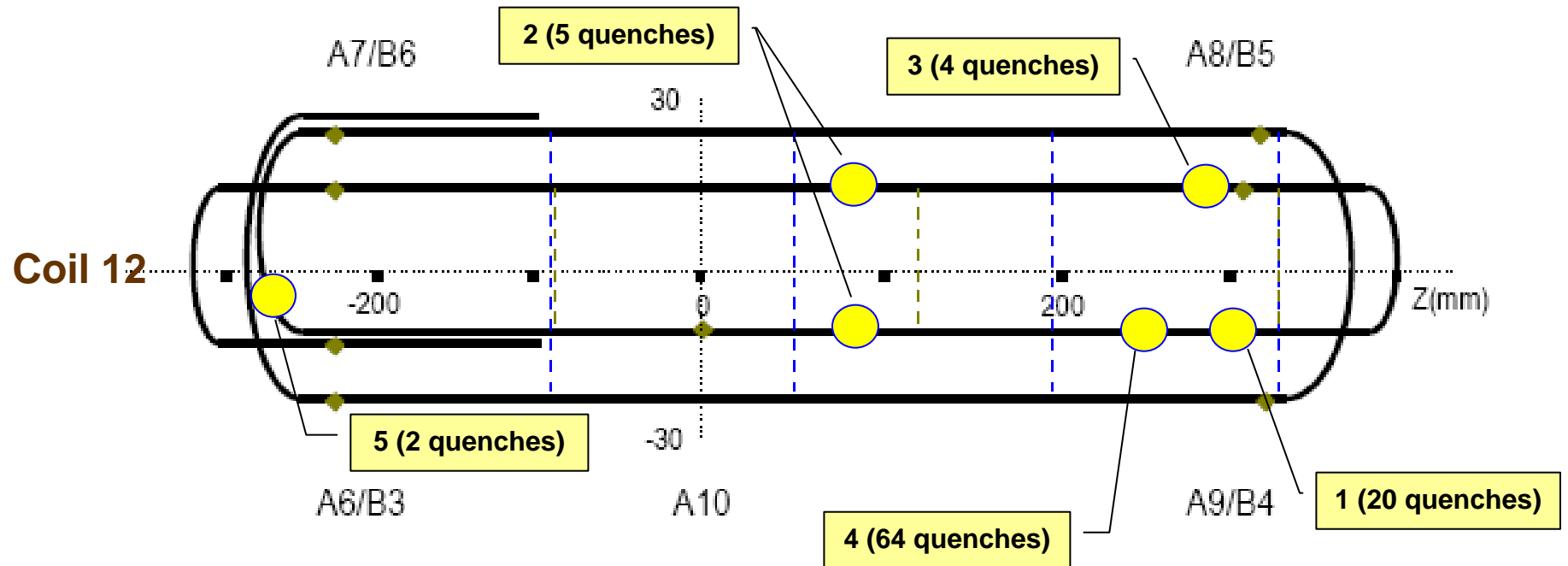
1: A10A9 and **A9A8** segments starting almost at the same time, **A8A6** follows
    in 5-6 *msec*.

2: Quenches in both **A10A9** and **A8A6** segments.

3: A8A6 is the first quenching segment, **A9A8** - very close to it.

4: A10A9 is the first quenching segment, then **A9A8, A8A6**.

5: Quench in ramp.

TQC02b Quench Positions at 1.9K

1: A10A9 and **A9A8** segments starting almost at the same time, **A8A6** follows in 5-6 *msec*
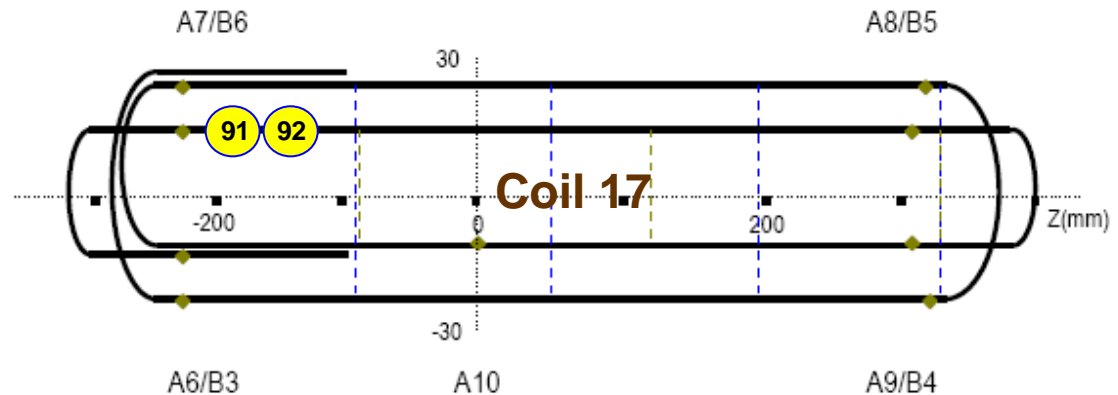
2: Quench in ramp
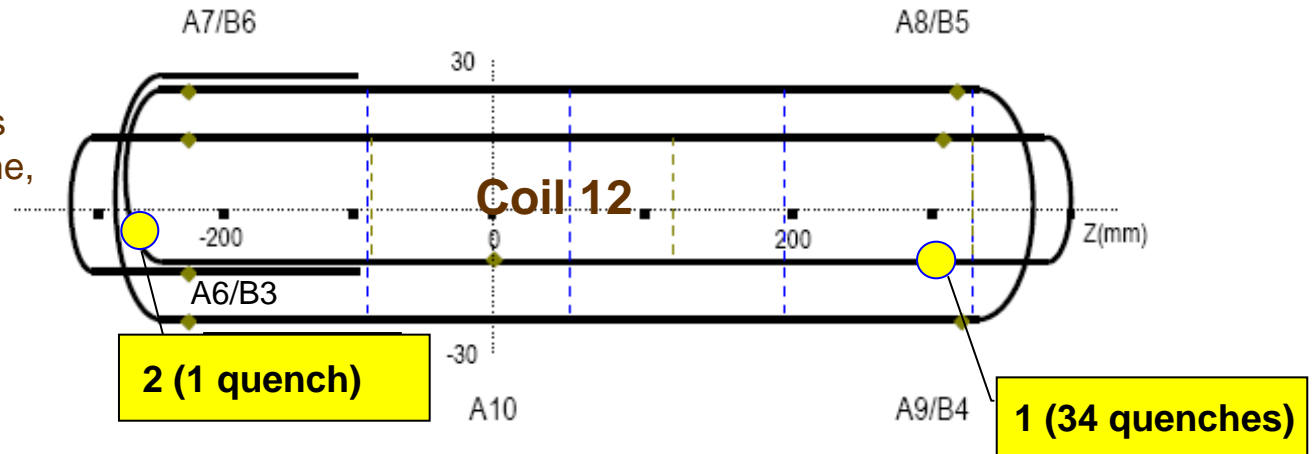
2 training quenches at 1.9K only; The first quenching segment is **A8A7**

High ramp rate quenches at 1.9K only in mid-plane segments

Few quenches during the heater tests

The highest quench current in the test:
~ 10.5 kA, quench #92, T=3.6K

2 (1 quench)

1 (34 quenches)

Did not return to 1.9K after 2nd thermal cycle.

TQC Preload and Quench Behavior

Preload at inner pole in TQC models (MPa)

TQC01b data is listed separately for coils with glued/non-glued outer poles.

Model No.	After Collaring	After Assy	After Cooldown	At Max field 4.5K	At Max Field 1.9 K
TQC01a	19	49	N/A	N/A	N/A
TQC01b	39/23	106/84	118/xx	39/xx	26/xx
TQC02E	54	108	N/A*	N/A*	N/A*
TQC02a	62	138	88	27	27
TQC02b	43	120	TBD	TBD	TBD

* Actual values unknown but gauges did not unload during excitation

% of SSL in TQC models

Model No.	Max % SSL at 4.5K	Max % SSL at 1.9K	Max Gradient at 4.5K (T/m)	Max Gradient at 1.9K (T/m)
TQC01a	72	87	154	200
TQC01b	86	90	178	200
TQC02E	87	79	201	199
TQC02a	68	65	157	164
TQC02b	85	78	175	173

All TQC 4.5K Training Quenches

Training at 4.5K of all TQC models is compared. Coils with potted parts show a steeper rise and earlier plateau, although all are used in an identical structure.

Outer pole potted

Outer pole mold released

Inner pole with stress relief slot